

Wire-Extrusion Process Disrupted By Voltage Sags

The Situation

At a wire-extrusion plant near Cleveland, Ohio, voltage sags originating from the utility distribution system were causing a wire-drawing process to malfunction, resulting in broken tungsten wire and hours of time spent restarting the manufacturing process. Although the whole plant was exposed to these voltage sags, they affected only the 200 or so final spooling machines in the wire-drawing process used to spool the fine-strand finished wire.

It takes nearly three days for a single machine to produce a full spool of wire, and if the wire breaks before the spool is less than half full, the entire spool is scrapped. The wire-extrusion company estimated losses in time and material due to voltage sags to be more than one-hundred thousand dollars per year. The supplying utility, FirstEnergy Corporation, along with EPRI's Power Electronics Applications Center (PEAC), conducted a power quality investigation at the plant to help resolve the problem.

bulbs. During the final drawing process, the wire is coated with a liquid graphite mixture and is then drawn through a series of heated dies that stretch the wire to the proper gauge. A capstan that is controlled by a DC motor pulls the wire through the process and feeds it to a spooler, which is controlled by an AC motor. Figure 1 shows a functional diagram of the final wire-drawing process.

Based upon its cursory inspection, FirstEnergy indicated that the elements of the wire-drawing process most susceptible to voltage sags may include one or more of the following:

- Main AC contactor
- Finished-wire spooler
- DC power supply for the capstan motor
- RPM feedback loop from the DC-motor gearbox
- Mechanical complexities of the wire-drawing process

Three engineers from FirstEnergy and PEAC visited the site with the following objectives:

- To induce voltage sags similar to the ones expected at the power terminals of the affected wire-drawing machines.
- To identify each potential weak link in the wire-drawing process.
- To develop a sag-tolerance curve for each process component.
- To propose solutions to the wire-breaking problem and to attempt to test the proposed solutions while on site.

Anticipating a 20- to 40-minute delay in restringing the wire each time the wire broke, the investigators determined that testing the wire extruder without pulling any wire would be a sufficient first step to determine the sag tolerances of the process equipment. To test the electrical process equipment, the investigators employed the Process Ride-Through Evaluation System, also called the "Porto-Sag," which is capable of inducing voltage sags and interruptions with user-selectable magnitude and duration. Voltage sags were injected into each of the poten-

Investigative Approach

Before contacting PEAC, FirstEnergy conducted a cursory inspection of the plant to assess the wire-making process. The plant's vertically-integrated wire-drawing process forms tungsten wire from raw tungsten. As the tungsten moves from one end of the plant to the other, approximately twenty operations transform tungsten ingots into rods, and ultimately into a filament-grade wire to be used in incandescent light

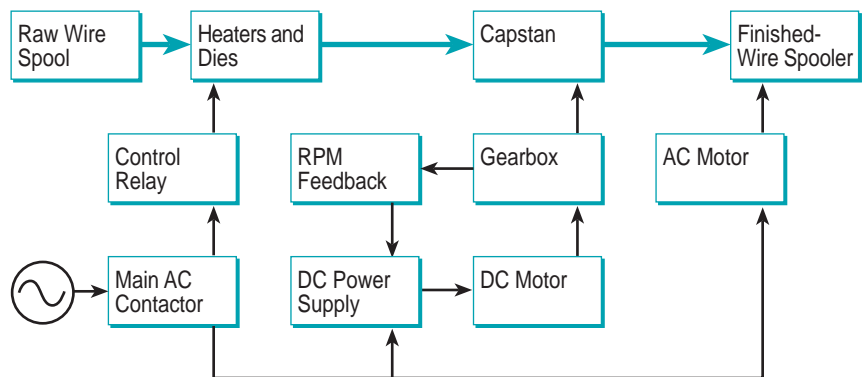


Figure 1. Functional Diagram of the Final Wire-Drawing Process

tial weak links of the process, and the electrical conditions of the process components were monitored with the Porto-Sag’s built-in oscilloscope. By varying the magnitude and duration of the applied voltage sags, investigators created sag-tolerance curves for each monitored process component. As shown in Figure 2, the sag-tolerance curve for the entire wire-drawing process reveals a susceptibility to many common voltage sags.

Findings

The Porto-Sag testing revealed that the DC-motor-controlled capstan immediately slowed down during voltage sags while the spooler continued to spin at its normal speed. The resulting tension between the capstan and spooler exceeded the tensile strength of the extruded tungsten, causing it to snap as shown in Figure 3. During a voltage interruption, both the DC and the AC motors stop. But because the capstan is driven directly by a gearbox, it quickly stops during a voltage interruption. The spooler, on the other hand, is driven by a one-way clutch. When the AC motor stops, the spooler continues to spin—similar to the driven wheel of a bicycle—coasting to a stop after the wire breaks.

Review of the data from the sag testing suggested that the DC power supply to the capstan was the weakest component of the wire-drawing process. To verify this conclusion, a 1-kVA constant-voltage transformer (CVT) was applied to only the AC spooler motor, thereby isolating the AC motor from the applied voltage sags. The CVT prevented the sag from directly affecting the AC spooler motor. As expected, the wire still broke, strongly suggesting that the capstan’s response to the voltage sags was causing the wire to break.

Next, the same CVT was installed between the DC power supply and the utility voltage source. The process was once again sagged to verify that a

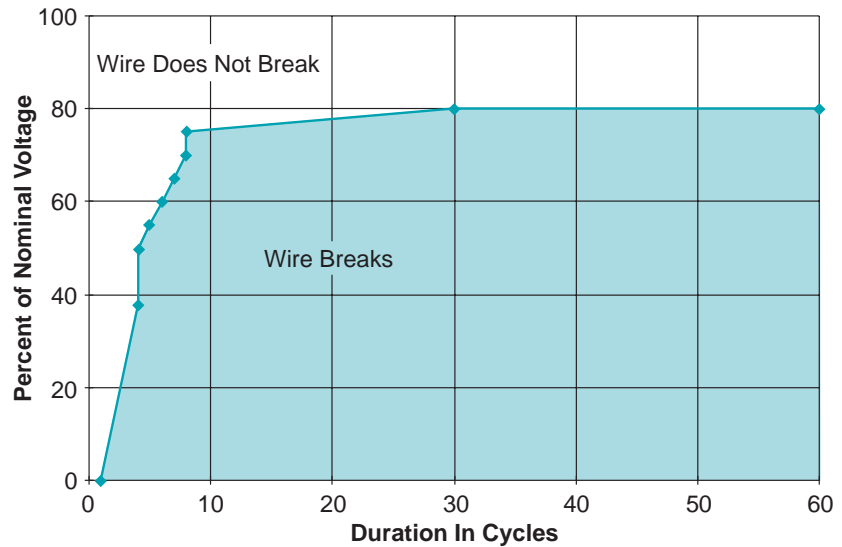


Figure 2. Sag-Tolerance Curve for the Entire Wire-Drawing Process

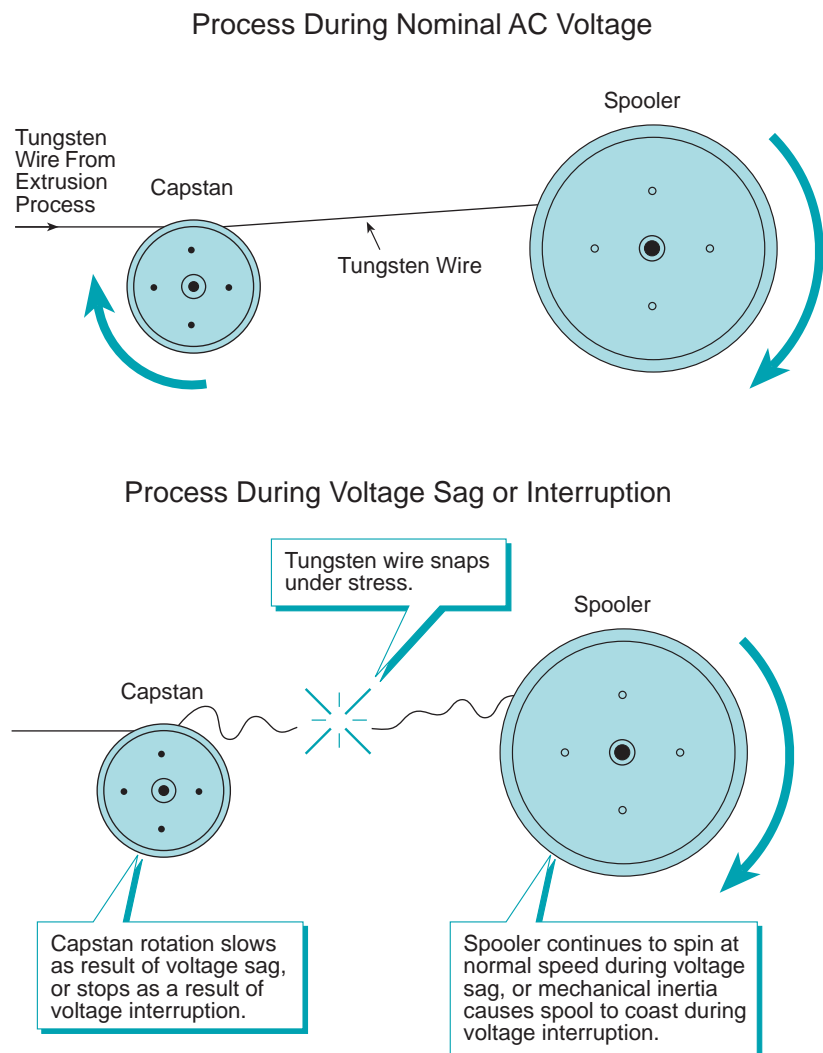


Figure 3. Point of Wire Breakage Between Capstan and Spooler

CVT would solve the problem. Still, the wire broke. By calculation, the 1-kVA CVT was large enough to support the DC power supply and therefore should have been a viable solution. However, monitoring the output voltage of the CVT during the sag testing showed significant oscillation of its output voltage, even during steady-state conditions.

Simultaneous monitoring of the DC power supply's input current showed that the power supply was half-wave rectified, drawing current only during one-half of the 60-hertz AC voltage. The resulting severely unbalanced current caused the CVT's output voltage to oscillate. Therefore, the investigators concluded that even a 2-kVA CVT may not have been able to regulate its output voltage during a voltage sag. As a result, they eliminated a CVT as a practical solution.

No Power Conditioning Required

After power conditioning was put aside, the power quality investigation led to the conclusion that the most cost-effective solution would be some type of mechanical shock absorber for the wire strand itself. The proposed solution, shown in Figure 4, was tested by physically adding some slack to the wire by holding the wire down with the shaft of a screwdriver as the capstan and spooler ran. When a sag was applied, the capstan slowed as before, but the screwdriver and the arm of the person holding the screwdriver were forced upward, preventing the wire from snapping.

The shock absorber was thus validated as a viable solution to the wire-breakage problem. The shock absorber would also work for voltage interruptions by providing enough resistance to stop the inertia of the spooler from snapping the tungsten wire.

By adding a properly designed guidewheel and spring assembly or

weight between the capstan and the spooler, the wire-snapping problem could be eliminated without the need of expensive power-conditioning devices. The estimated cost for the spring and guidewheel solution was approximately 50 dollars per machine, or 10,000 dollars for all 200 machines,

although more expensive dancer-arm tensioners are available for such an application. Based upon the estimated cost of 100,000 dollars per year in scrap and downtime, the shock absorbers would pay for themselves in less than two months.

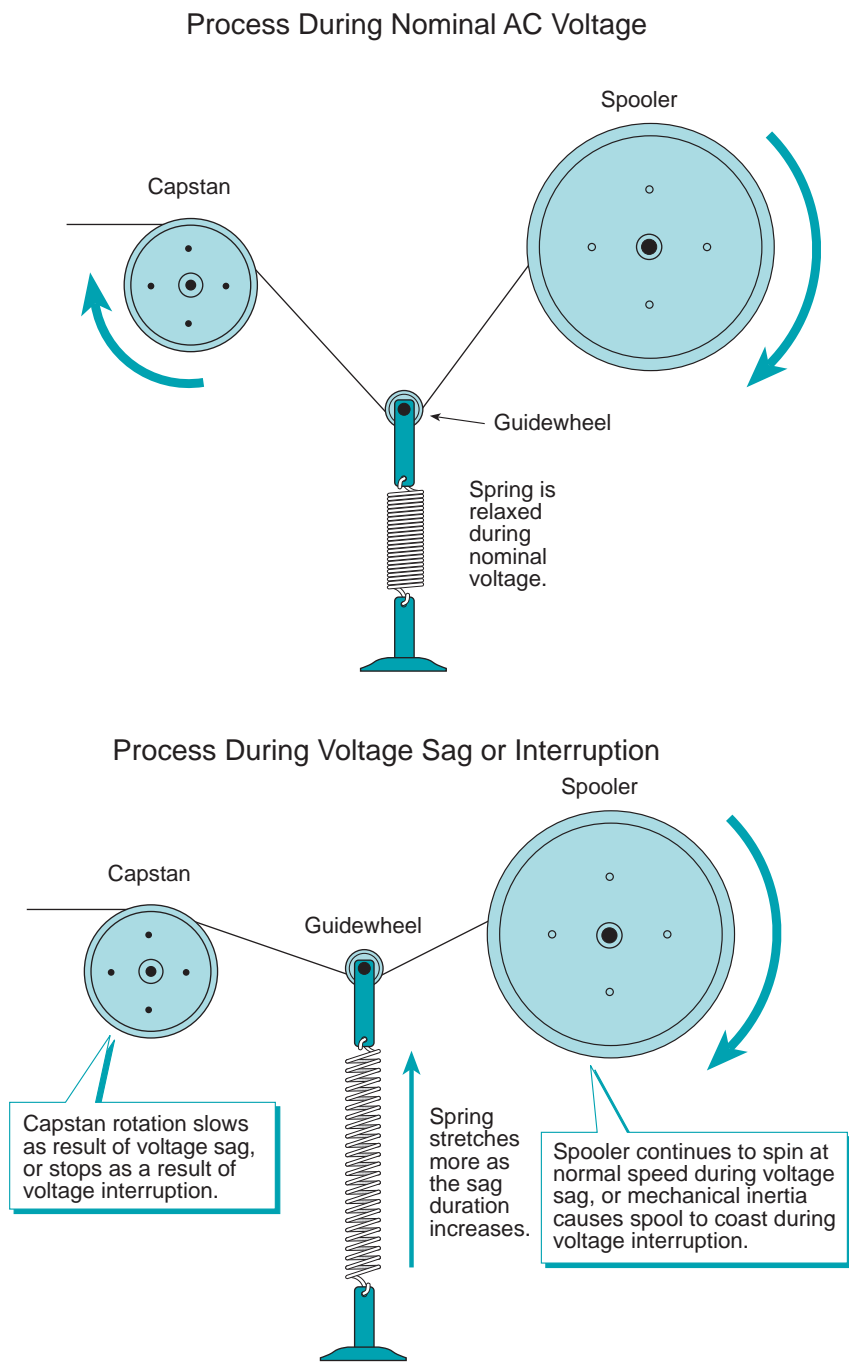


Figure 4. Proposed Solution to Prevent Wire Breakage During Voltage Sags and Interruptions

Conclusion

The unexpected mechanical solution illustrates an important point for power quality troubleshooters: Understand all process interactions before recommending power-conditioning solutions for mechanically complex processes. While a large power-conditioning device probably

would have solved the wire-breakage problem, the up-front cost to the customer would have been significant and would have greatly extended the payback time. The probability of an industrial customer being able to justify a multi-year cost payback is not likely. Therefore, a cost-effective mechanical solution meant the difference between a lingering problem and a satisfied customer.

ACKNOWLEDGMENTS

Many thanks to FirstEnergy Corporation, which sponsored the investigation, and to Allen Morinec of FirstEnergy for his participation in the investigation and the production of this PQTN Case Study.

The Power Electronics Applications Center (PEAC) is a center of the Electric Power Research Institute, a nonprofit institute that conducts research on behalf of electric utilities. PEAC's mission is to support electric utilities in their efforts to understand and resolve power quality problems and system compatibility issues; to help utilities solidify durable, beneficial relationships with their customers, manufacturers, and standards organizations; and to empower them with knowledge via power quality training and publications. This PQTN Case Study is one of many publications available to qualified utilities and their customers.

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